A micromanipulation cell including a microtools changer.

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Cédric Clévy, Arnaud Hubert, Joel Agnus, Nicolas Chaillet
LAB UMR CNRS 6596, ENSMM, UFC
24, rue Alain Savary
25000 Besançon, FRANCE

Abstract

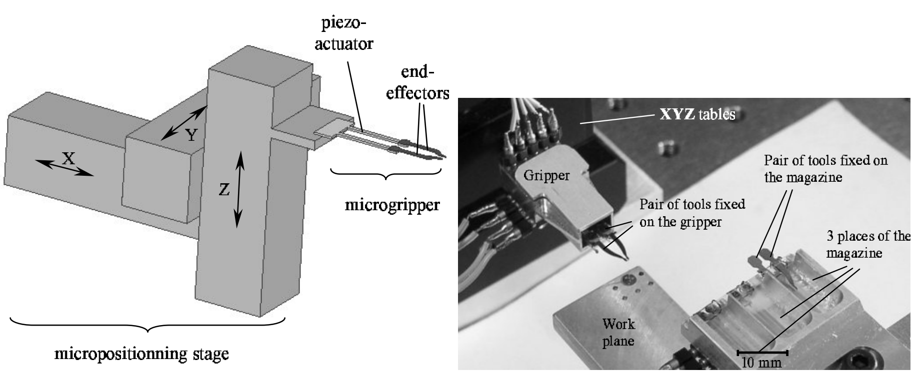
This paper describes the structure of a flexible micromanipulation cell designed to perform precise pick and place operations of objects with typical sizes from 20 to 500 μm. This cell is composed of three linear stages (X-Y-Z), a four degrees of freedom microgripper and a microtools changer.

Introduction

Numerous of recent works concerning micromanipulation stations exhibit the growing needs of micromanipulators able to work automatically and flexible enough to be used for several kind of applications, notably in confined spaces (SEM or TEM chambers or more generally microfactories)[1].

In this aim, we have developed a micromanipulation cell composed of three elements:

- a commercially available three linear DOF micropositionning stage (for pick and place tasks, see figure 1-a),
- a four DOF piezoelectric gripper fixed on it and developed to increase the manipulation dexterity (section I),
- a new microtools changer which has been developed as a way to reach the flexibility required in microrobotic cells (see figure 1-b). The tools are here the end-effectors fixed at the tip of the microgripper (section II).



(a) (b)

Figure 1: Design of the micromanipulation cell: (a) schematic view of the three X-Y-Z axis micropositionning stage and four degrees of freedom microgripper (b) Focus on the microgripper and the tools magazine.

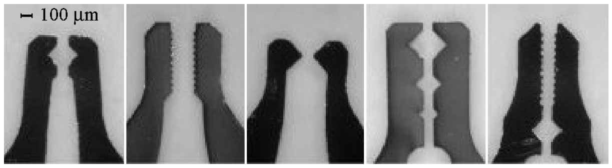


Figure 2: Different kind of tools available.

I Characteristics of the gripper

The micromanipulation cell is constituted by three linear micropositioning stages (figure 1-a) allowing tasks such as pick and place. It's overall dimensions are 100x100x100 mm^3. The stages [1] are actuated by DC motors with 25 mm of stroke, 0.1 μm of unilateral repeatability and permit a closed loop control.

The gripper is constituted by a monolithic piezoelectric actuator and a pair of tools made of nickel (figure 1-a and 3). Several kinds of pairs of tools are available depending on the size, shape or consistency of the object to manipulate (figure 2). The actuator is composed of two piezoelectric ceramic plates with a film of conductive glue between both. Four electrodes per finger are coated on the surface of these plates. Such designed (details are given in [2] and [3]), each of both finger's gripper is able to move independently from the other vertically (+/- 200 μm of stroke [2]) and horizontally (+/- 80 μm of stroke [2]) allowing four degrees of freedom. These possibilities of the gripper are useful to perform dexterous micromanipulations (rotation or insertion of an object) or to correct the eventual missaligning of the tools due to the fabrication process. The measured (gripping stroke and first resonance frequencies) and the estimated by model (forces) characteristics of the gripper are:

- 320 μm of gripping stroke between the totally open and close position,
- 55 mN of blocking force (by finger in the Y direction),
- 10 mN of insertion force (Z direction),
- 1000 Hz of first resonance frequency for the grip motion (Y direction),
- 400 Hz of first resonance frequency for the insertion motion (Z direction).

Finally a user interface, developed with Borland Builder C++ allows to control as well the X-Y-Z stages as the four degrees of freedom of the gripper by using a joystick.

II The tools exchange principle

To develop a micromanipulation cell flexible enough to achieve a sequence of manipulation tasks, different strategies exist. As explained in section 1, different kind of tools are necessary in regard with the diversity of the objects to manipulate (shape, size, consistency). The first strategy consists in using several micromanipulation cells, each of them able to perform one kind of manipulation task. The second one is to develop a system able to change the gripper only. Finally, the last solution is to exchange only the tools. In regard with flexibility gains and the compact size available, the last solution is the best

[1]Manufactured by the PI company.
[2]Stroke given for a +/- 100V as supply voltage.

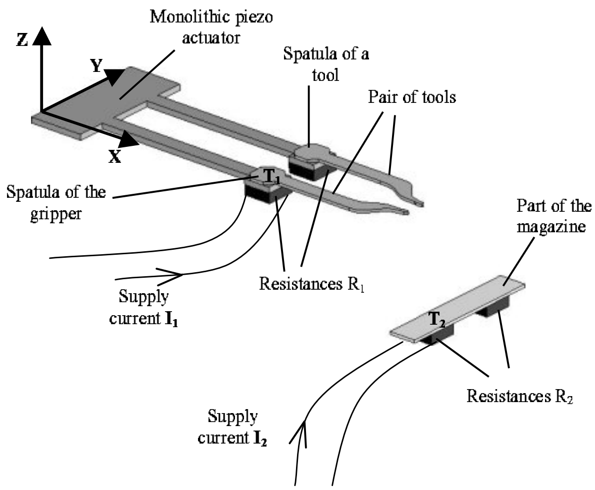


Figure 3: Schematic view of the gripper and a part of the magazine. Here the pair of tools is fixed at the tip of the actuator.

[4]. For this reason, we have designed a tools changer able to exchange automatically the two tips (tools) of the gripper.

Based on the use of a thermal glue, the developed system allows to fix the pair of tools either on the actuator of the gripper or on a magazine (figure 3). The thermal glue used [3] is solid at room temperature and liquid at 65 ˚C and hundreds of liquefaction/solidification cycles are possible without loss of properties. The operating cycle of a microtools exchange is described figure 4 and allows the succession of two elementary micromanipulation tasks. The first one consist in making a pile of cubic parts (100 μm of side size) needing tools with a flat active side (figure 2). The second one is the pick and place of a micro gear (140 μm of cross section diameter) requiring a different kind of tools. The thermal glue is placed at the contact between tools and the actuator and also between the tools and the magazine. The liquefaction of the glue is generated by surface mounted devices resistances fixed at the tip of the actuator and on the magazine (figure 3).

Experiments on this new system based on hundreds of automatic tools exchanges show a maximum position error between two consecutive tools exchanges of 4.2 μm, 2.8 μm and 5.4 μm on the X, Y and Z axis respectively with a distribution close to a gaussian distribution (details available in [5]).

First experiments (thermal and degassing characterization) in a vacuum chamber has also been performed proving that this tools changer can be used in a vacuum environment. Moreover, 300 mN can be applied at the extremity of a tool before breaking the glue film. This value is higher than the gripping force (55 mN per finger) but lower than the maximum force before breaking the actuator (600 mN).

This micromanipulation cell is currently used to achieve assembly tasks with the adapted tools. The flexibility of this station enables a succession of different kind of tasks.

Conclusion

[3] Commercially available under the name of crystalbond 555 HMP by Aremco Products inc.

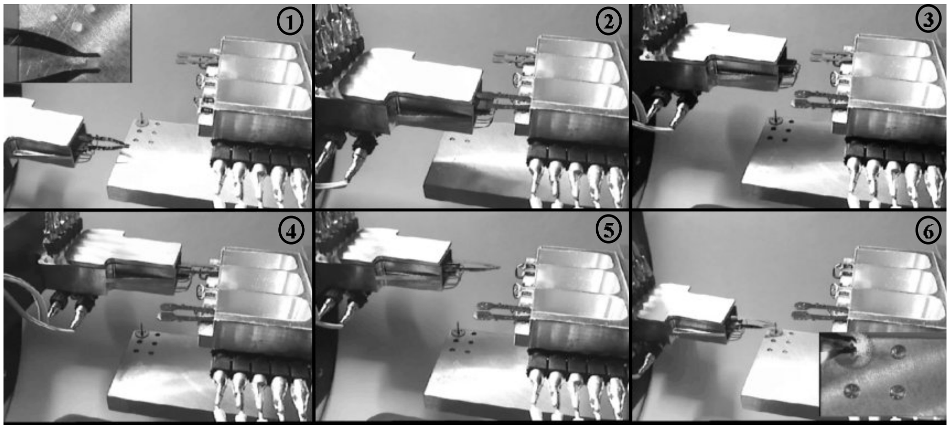


Figure 4: Successive steps for exchanging tools: (1) manipulation of a cubic part (2) the gripper releases the pair of tools in the magazine firstly by cooling down the glue between tools and magazine and secondly by heating the glue between tools and actuator (3) reaching the position to take the second pair of tools (4) cooling down the glue between tools and actuator and heating the glue between tools and magazine (5) taking away the second pair of tools (6) manipulation of a circled section gear.

Composed of three linear stages, a piezoelectric microgripper and a micro tools changer, the micromanipulation cell is flexible enough to allow the succession of micromanipulation tasks. The four degrees of freedom skilled gripper permits the pick, place, rotate or insertion of an object from 20 to 500 μm in size. The microtools changer presents satisfactory enough characteristics (precision and thermal characteristics in a vacuum environment) to be used in very confined spaces such as in a SEM, TEM chamber or more generally in a microfactory.

To reach the goal of developing a fully automated and flexible micromanipulation cell, future works will focus on the integration of force sensors and vision capabilities.

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